

Which factors does the diffusion of ISO 50001 in different regions of the world is influenced?

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ABSTRACT

Non-renewable fuels are the world's main source of energy. However, the decrease in supply, increased demand, higher product costs and adverse effects on the environment led to the need to create the ISO 50001: 2011 standard to implement the Energy Management System (EnMS) in order to increase energy efficiency and reduce the emission of greenhouse gases (GHG). Thus, the objective of this work was to characterize the diffusion process of the ISO 50001 standard around the world and what are the main factors that determine the adoption of EnMS in the different regions of the planet. For this, multiple regression models were used for the data of certification number and environmental, social, economic indicators, climate change and energy mining. Thereby it was observed that Europe has the highest number of ISO 50001 certifications and Asia is the fastest growing region. Among the countries Germany and the United Kingdom are those with the greatest diffusion of ISO 50001, but China has been increasing its diffusion with each year. Thus, the concern with climate change is the main factor that determines the adoption of the EnMS by the companies in the most diverse countries.

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1. Introduction

The waste of energy and increasing greenhouse gas emissions (GHG) from inefficient energy use by companies has become a global concern. In 2016, the world energy production was 13764 megaton oil equivalent (Mtoe) with fossil fuels accounting for 81% of this total (IEA, 2018). These energy sources are responsible for GHG emissions which contribute to global warming and, consequently, anthropogenic climate change (Li and Tao, 2017; Weisser, 2007). Seeking to reduce greenhouse gas emissions and implement a more energy efficient management model, the International Organization for Standardization (ISO) launched the Energy Management Systems (EnMS) ISO 50001:2011. This international standard is part of a series of standards such as ISO 9001 and ISO 14001 (ISO, 2017). ISO 50001 was designed to promote best energy management practices and reductions in GHG emissions (Piñero, 2009). The adoption of EnMS has led to the improvement of energy performance and efficiency indicators in industry (Chiu et al., 2012), as well as reducing GHG emissions (de Sousa Jabbour et al., 2017). Thus, the adoption of EnMS could avoid 6500 million metric

tons (Mt) of CO₂ from being emitted by 2030 (McKane et al., 2017). The effects of adopting EnMS to reduce GHG emissions are expected in the future, while energy efficiency can be achieved in the present. However, for this to happen, it is necessary that the standard be diffused in the largest number of companies, from the various industrial sectors, in most countries in all regions of the world. According to data from 2011 to 2015, the standard increased from 474 to 23092 certifications, being present in all regions of the world: Asia 2745; Europe 17099; Americas 152; Middle East 152 and Africa 55 (ISO, 2017). Despite this, the distribution of ISO 50001 is very uneven across regions. As a result, Europe accounts for 74.04% of worldwide certifications.

The diffusion of the ISO standard is a process that can be influenced by environmental, economic and socio-cultural factors of each region, country and/or industrial sector (Neves et al., 2017). Country diffusion data has been used to carry out worldwide certification forecasts (To and Lee, 2014). Therefore, different factors of influence in the diffusion of the standard were observed (Salgado et al., 2015). Thus, through logistic models and multiple regression analyses, it was sought to quantify the influence level of each of the factors in certain countries or regions (Franceschini et al., 2004; Castka and Corbett, 2015; Neves et al., 2017). In general, countries with the highest number of certifications have been used (Casadesús et al., 2008; Marimon et al., 2010). In fact, in these

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countries, there is a greater distribution of certifications among companies. In the case of ISO 50001, countries with the highest number of certifications are expected to have higher energy efficiency and lower GHG emissions. However, this relationship is still not well established and the effects of the implementation of EnMS continues to be questioned (Böttcher and Müller, 2014; Fiedler and Mircea, 2012; Therkelsen et al., 2013; Trianni et al., 2013). Nonetheless, assessing the factors that influence the diffusion of ISO 50001 can help understand what drives a company to adopt EnMS in countries with the highest number of certifications around the world. In addition, the data can be used to draw a profile of the industries that most adopt EnMS and with this, to make predictions about the diffusion stage of ISO 50001 in these countries. Because of this, this seminal work sought to establish, through multiple regression analysis, the main environmental, energy and mining, economic, climate change and socio-cultural factors that influence the diffusion of ISO 50001, and consequently, the adoption of EnMS in the country with the highest number of certifications in the last years. For this purpose, some questions guided this study:

- How much of the diffusion behaviour is explained by the factors?
- Do the environmental, energy and mining, economic, climate change and socio-cultural factors act together or in isolation in the diffusion of ISO 50001?
- Is there any predominant factor among the factors tested?

In order to answer these questions, this article was structured as follows: initially, an introduction to contextualize the problem, followed by a literature review to provide the initial basis for better understanding the results. Next, material and methods with the discretion of obtaining the data and detailing the analyses used in the work. After this section, the results and discussion present graphs and tables, besides the exposition of the authors' thinking in relation to the current scientific knowledge. Finally, the conclusion answers the questions raised and proposes topics to be investigated in future works.

2. Literature review

2.1. ISO 50001

ISO 50001 is another voluntary standard, as well as ISO 9001 and ISO 14001, created by the International Organization for Standardization (ISO) and launched in 2011, which offers benefits to large or small companies, private or public, of goods or services involving production, consumption or distribution of energy (Chiu and Lo, 2015; Dzene et al., 2015; Yücel and Halis, 2016). The standard establishes the guidelines for implementation, maintenance, and evaluation of Energy Management Systems (EnMS) (ISO, 2011). EnMS aims to make the productive activities of the industrial sectors more efficient in the use of energy. This will improve energy efficiency and reduce emissions of greenhouse gases (GHG) (McKane et al., 2009).

Energy efficiency seeks to use less energy to reduce financial costs, operating costs, use of resources and emission of GHG without compromising incomes (Worrell et al., 2003). For this purpose, the adoption of EnMS is fundamental, to establishes a network for continuous improvements in energy efficiency in the productive processes of companies (Pelser et al., 2018). It allows the integration with the Quality Control System (ISO 90001) and Environmental Management System (ISO 14001) (Chiu et al., 2012).

All energy systems generate emissions of GHG contributing to climate change. GHG emissions resulting from the use of energy need to be monitored throughout its production cycle. This is

important for mitigation strategies in impacts caused by the production or use of energy (Weisser, 2007). Although effective energy management is the main objective of EnMS, it contributes to the reduction of GHG emissions through guidance on how to measure, document and report energy efficiency and reductions in GHG emissions (Piñero, 2009). In the future, EnMS could be a requirement for companies seeking to increase energy efficiency and reduce GHG emissions (Zawaydeh, 2015). However, for this to happen, a high diffusion of EnMS is necessary in the short term.

The ISO 50001 diffusion process by companies in countries with the highest adoption rate in the world is still poorly understood. And trying to figure out the factors that lead to this behaviour can help map the process of diffusing ISO 50001 in countries or regions that have low diffusion of the standard (Hikichi et al., 2017). This contributes to certification bodies, technical committees, and government accreditation agencies to promote the adoption of EnMS in several countries and industrial sectors, which can contribute to increasing energy efficiency and reducing GHG emissions around the world (Boiral et al., 2017; Di Noia and Nicoletti, 2016; To and Lee, 2014). Among the factors that may be related to the diffusion of ISO 50001 is the diffusion of ISO 9001 and ISO 14001, since these standards work in an integrated way.

2.2. Factors related to the diffusion of ISO 50001

In the diffusion of ISO standards, several factors can influence a company's decision to adopt a quality, environmental or energy management system (Neves et al., 2017; Dzene et al., 2015; Salgado et al., 2015). In addition, particularities of regions, countries and industrial sectors are decisive for this process (To and Lee, 2014). In the case of ISO 50001, the factors that may influence companies in the adoption of EnMS are related to the use, supply and impacts caused by energy. Thus, indicators of various aspects (economic, environmental, etc.) that are related to energy in different regions and countries become important for understanding the diffusion of ISO 50001 (Marimon and Casadesús, 2017).

However, these indicators do not always have data series accompanying the diffusion of ISO 50001, or are not available for certain countries. Thus, the synchronization between the data of the indicators and the diffusion of ISO 50001 is not so usual. Nevertheless, some of the indicators that can be used as diffusion influence factors fulfil these conditions. In this case, Total natural resources rents (% of GDP) is an environmental indicator that is the income obtained through all the natural resources of the country. That is, the sum of incomes of oil, natural gas, coal (hard and soft), ores and forests (World Bank, 2016). The indicator Adjusted savings: energy depletion (% of GNI) measures the ratio between the value of the energy resource stock and the remaining time of the country's energy reserve (limited to 25 years) as a percentage of its GNI. Energy resources include coal, crude oil and natural gas (World Bank, 2016), while, Combustible renewables and waste (% of total energy) indicates the percentage of renewable energy and combustible waste, which includes solid biomass, liquid biomass, biogas, industrial waste and urban waste in the country, in relation to the total energy use (World Bank, 2016). In order to evaluate the energy consumption from coal, oil and natural gas of a country in relation to the total energy consumed, it was used the indicator Fossil fuel energy consumption (% of total) (World Bank, 2016). The percentage of the total energy of countries that do not produce carbon dioxide when generating energy was assessed through the indicator Alternative and nuclear energy (% of total energy use). This includes hydropower and nuclear, geothermal and solar energy, among others (World Bank, 2016). Electricity production from oil, gas and coal sources (% of total) is an indicator that evaluates the percentage of total energy used in the country that is produced by

crude oil or by-products, natural gas but excluding natural gas liquids, and coal (brown coal, lignite brown, furnace, gas coke, coke oven gas, blast furnace gas and peat) (World Bank, 2016). The use of primary energy prior to conversion to other end-use fuels was assessed using the Energy use (kg of oil equivalent per capita). This indicator takes into account the country's production plus imports and inventory changes, minus the exports and fuels supplied to ships and aircraft involved in international transportation (World Bank, 2016). Finally, the percentage of the country's total energy produced from renewable sources, excluding hydropower, including geothermal, solar, tidal, wind, biomass and biofuels was measured through the indicator Electricity production from renewable sources, excluding hydroelectric (% of total) (World Bank, 2016). All these indicators are obtained for each country and their different realities in the use and supply of energy.

Another important factor in the diffusion of ISO standards is the way they interact with patterns with longer release times. Once, integration among standards is an objective of the International Standards Organization (Heras-saizarbitoria and Boiral, 2013). In this context, the ISO 50001 standard is also part of this integration model joining the ISO 9001 and 14001 standards. However, for this to work, companies that have adopted these standards must implement EnMS. However, environmental, economic, energy-related and climate change factors may be more determinant for the diffusion of ISO 50001.

3. Materials and methods

This study used multiple regression models to determine which factors are most relevant in the diffusion of ISO 50001 in countries with the highest number of certifications worldwide.

3.1. Data collection

The analysis of ISO 50001 certificates was performed using data from the ISO Survey platform in 2017 with data presented until 2016. It considered the number of ISO 50001 certificates for each country that had the number of certifications above 100 in 2016 (ISO, 2017). Environmental, energy and mining, economic, climate change and socio-cultural indicators were investigated as influence factors in the diffusion of ISO 50001. The indicators were selected based on the relation with energy issues. The classification of the indicators was established by the World Bank, from which the data were obtained in the period from 2011 to 2015 (World Bank, 2016) (Table 1). While diffusion data of ISO 9001_(n-1) and ISO 14001_(n-1) in the period from 2010 to 2014 were obtained from the ISO Survey platform in 2017 (ISO, 2017). The diffusion data of ISO 9001 and ISO 14001 were considered as factors of socio-cultural influence because of the role of these standards in the adoption of new standards by companies (Casadesús et al., 2008). Thus, using the number of certifications of these standards in the previous year can

explain the number of ISO 50001 certifications in the following year. It is worth mentioning that, in the literature, we find research that also use ISO 9001_(n-1) and ISO 14001_(n-1) as factors in the diffusion models. The use of the n-1 notation means that we use the number of certifications from the previous year of the ISO 9001 and ISO 14001 indicators. This suggests that the influence of an earlier factor on the adoption of another factor cannot be measured in the same year (Neves et al., 2017). Thus, we always use the number of certifications from the previous year.

3.2. Modelling

Initially, a characterization of the diffusion of ISO 50001 certifications around the world between regions and countries was carried out, where a density map and evolution curves of ISO 50001 were elaborated. From there, the countries with number of certifications above 100 in 2016 were ranked. For the selection of predictors of the environmental, energy and mining, economic, climate change and socio-cultural factors, the adjustment of the multiple regression models were performed using the data of ISO 50001 for each country in the period of 2011–2015 as response variable. Countries without useable registration data at the time were not used for model adjustment (e.g. China). Due to the low number of observations (5 per country), a Pearson correlation matrix was calculated where the predictive variables with the highest values of Pearson correlation and p-value below 0.05 were selected (Dohoo et al., 1997; Knofczynski and Mundfrom, 2008; Lin, 2008; Pawlicz and Napierala, 2017). Therefore, the predictor variables were tested in different combinations and the models were chosen according to the lowest value for Akaike's Information Criterion (AIC) and highest adjusted coefficient of determination (R^2_{adj}). The estimation of the parameters of the multiple regression models was performed using the least squares method with Student's t-test, while significance was performed through the F test of ANOVA. Based on the choice of the model, the residue analysis was carried out with respect to the assumptions: Normality, through the Shapiro-Wilk test; Homoscedasticity, through the Breusch Pagan test; and Dependence, through the DurbinWatson test. All the statistical analyses were performed using the computing environment R, version 3.5.1 (R Core Team, 2018).

4. Results and discussions

4.1. The diffusion of ISO 50001:2011

ISO 50001certifications are spread across 193 countries in all regions of the world. In 2016, the number of certifications reached 20203 and Europe was the region with the highest number of certifications. Asia had a high number of certifications as well; while in the rest of word, ISO 50001 numbers were low.

The countries with the highest number of certifications in 2016

Table 1

Indicators used for modelling the number of ISO 50001 certifications. Data obtained in the period 2011–2015.

INDICATOR NAME	ACRONYMS	REFERENCE
Total natural resources rents (% of GDP)	T.N.R.R.	World Bank (2016)
Adjusted savings: energy depletion (% of GNI)	A.S.E.D.	World Bank (2016)
Combustible renewables and waste (% of total energy)	C.R.W.	World Bank (2016)
Fossil fuel energy consumption (% of total)	F.F.E.C.	World Bank (2016)
Alternative and nuclear energy (% of total energy use)	A.N.E.	World Bank (2016)
Electricity production from oil, gas and coal sources (% of total)	E.P.O.G.C.S.	World Bank (2016)
Energy use (kg of oil equivalent per capita)	E.U.	World Bank (2016)
Electricity production from renewable sources, excluding hydroelectric (% of total)	E.P.R.S.E.H.	World Bank (2016)
Certificates Count ISO 14001 _(n-1)	ISO 14001 _(n-1)	Neves et al. (2017)
Certificates Count ISO 9001 _(n-1)	ISO 9001 _(n-1)	Neves et al. (2017)

Table 2

List of countries with the highest number of ISO 50001 issued certificates in 2016 (ISO, 2017).

Country	Number of ISO 50001 certifications
Germany	9024
United Kingdom	2829
Italy	1415
China	1015
France	759
India	570
Hungary	546
Spain	465
Czech Republic	369
Taipei	298
Thailand	255
Austria	224
Ireland	137
Russia	118
Denmark	118
Turkey	115
Poland	112

were Germany with 9024, the United Kingdom with 2829, Italy with 1415 and China with 1015 (Table 2). These countries accounted for ~70.69% of the number of certifications (ISO, 2017).

Of the 18 countries with the highest number of ISO 50001 certifications, 14 were on the European continent and 4 on the Asian continent. As a result, the global evolution of the standard assumed an exponential growth (Fig. 1) and the number of certifications increased from 459 to 20258, an increase of 4313.51%. This global growth of ISO 50001 was a consequence of the growth of the standard in most regions of the world, mainly Europe, East Asia and Pacific (Fig. 2).

Europe was the region with the highest number of certifications 17099, an increase of 3625.27%, while East Asia and Pacific, driven by China, presented the highest growth in certifications, 4157.14%. Observing the ratio number of certifications per number of countries, Europe remains at the forefront with 427 certifications by country, while Central and South Asia with ~165, and East Asia and Pacific with 130 certifications. Although the number of certifications in the other regions was low, all of them presented growth in this period. Europe, Germany, the United Kingdom and Italy accounted for 77.60% of certifications, while in East Asia and Pacific, only China was responsible for 48.65% of certifications. In Central and South Asia, India accounted for 86.49% of ISO 50001 certifications.

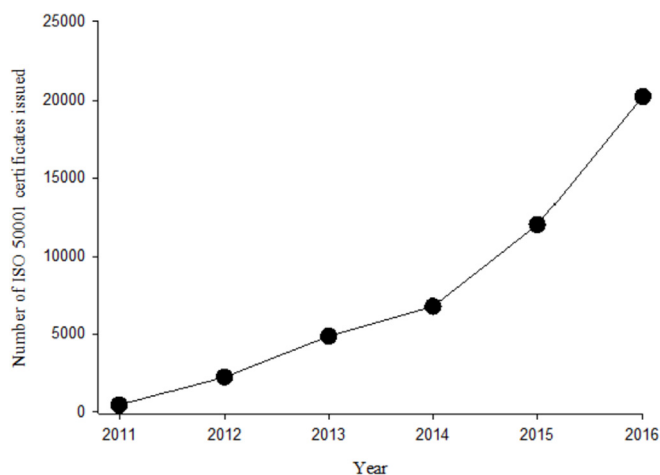


Fig. 1. Diffusion of ISO 50001 certification in the world from 2011 to 2016 (ISO, 2017).

In general, the number of certifications is related to the degree of development of the country and, consequently, to its industrial sector. Therefore, regions or countries with the highest number of certifications have a high degree of development (Heras-saizarbitoria and Boiral, 2013). Thus, Europe owning the largest number of companies with EnMS is a consequence of its advancement in environmental and energy issues. This was also observed for ISO 9001 and ISO 14001 (Hikichi et al., 2017a,b; Marimon et al., 2011; Neumayer and Perkins, 2004). Outside Europe, China and India were the countries with the largest number of companies that adopted EnMS. This was due to substantial growth in primary energy demand of these two countries over the last decades (Trianni et al., 2013). However, countries with high-energy demand such as the USA and Canada seem to have little interest in obtaining these certifications. It turns out that in these countries, there are often specific legislations for the management of energy use by companies (Tanaka, 2008).

The diffusion of ISO 50001 shows similar behaviour to that of the other standards, which starts with a few companies adopting the standard and soon thereafter assume an exponential growth until reaching the saturation stage, where certification and decertification assume very close rates (Casadesús et al., 2008; Wisdom et al., 2014). At this time, ISO 50001 is in the first stage of diffusion, when growth rates are high. This, by ISO standards, means that the adoption of EnMS is in the expansionist stage, and can grow even more in the coming years (Casadesús et al., 2008). Compared to more well-known standards such as ISO 9001 and ISO 14001 that have reached maturity, it opens up a prospect for more companies to adopt EnMS in the future.

4.2. Factors that affected the diffusion of ISO 50001

The environmental, energy and mining, economic, climate change and other ISO standards (ISO 9001 and ISO 14001) indicators were tested as predictor variables in the multiple regression models using the number of ISO 50001 certifications of each country with response variable. Among the several predicted variables tested, those that assumed the greatest influence in the diffusion of the ISO 50001 certifications for each country are presented in Table 3.

Among the variables tested, Electricity production from renewable sources, excluding hydroelectric (% of total) (E.P.R.S.E.H.) is the one that influences the diffusion of ISO 50001 in five countries, while ISO 14001_(n-1) has influence in four countries and ISO 9001_(n-1) in three countries.

The variable Adjusted savings: energy depletion (% of GNI) (A.S.E.D.) was present in two countries, while the variables Alternative and nuclear energy (% of total energy use) (A.N.E.) and Energy use (kg of oil equivalent per capita) (E.U.kg.of.oil.capita) were observed only in one country each. Among the twelve countries evaluated, eight were influenced by only one factor, while four were influenced by two factors. Among the countries with two influence factors are the United Kingdom, Czech Republic, Austria and Poland. It has been observed that the factor changes its influence in relation to the diffusion of ISO 50001 according to the country. In this way, Electricity production from renewable sources, excluding hydroelectric (% of total) which has a positive influence on ISO 50001 in Germany, Italy and Poland has shown the opposite effect in the UK and Czech Republic.

This behaviour was also observed for ISO 9001_(n-1), which had a positive influence in Denmark, but a negative influence in Russia and Spain. However, some variables maintain their effect regardless of the country that occurs. For example, ISO 14001_(n-1) had a positive influence in the four countries in which it was shown, while Adjusted savings: energy depletion, on the other hand, had a

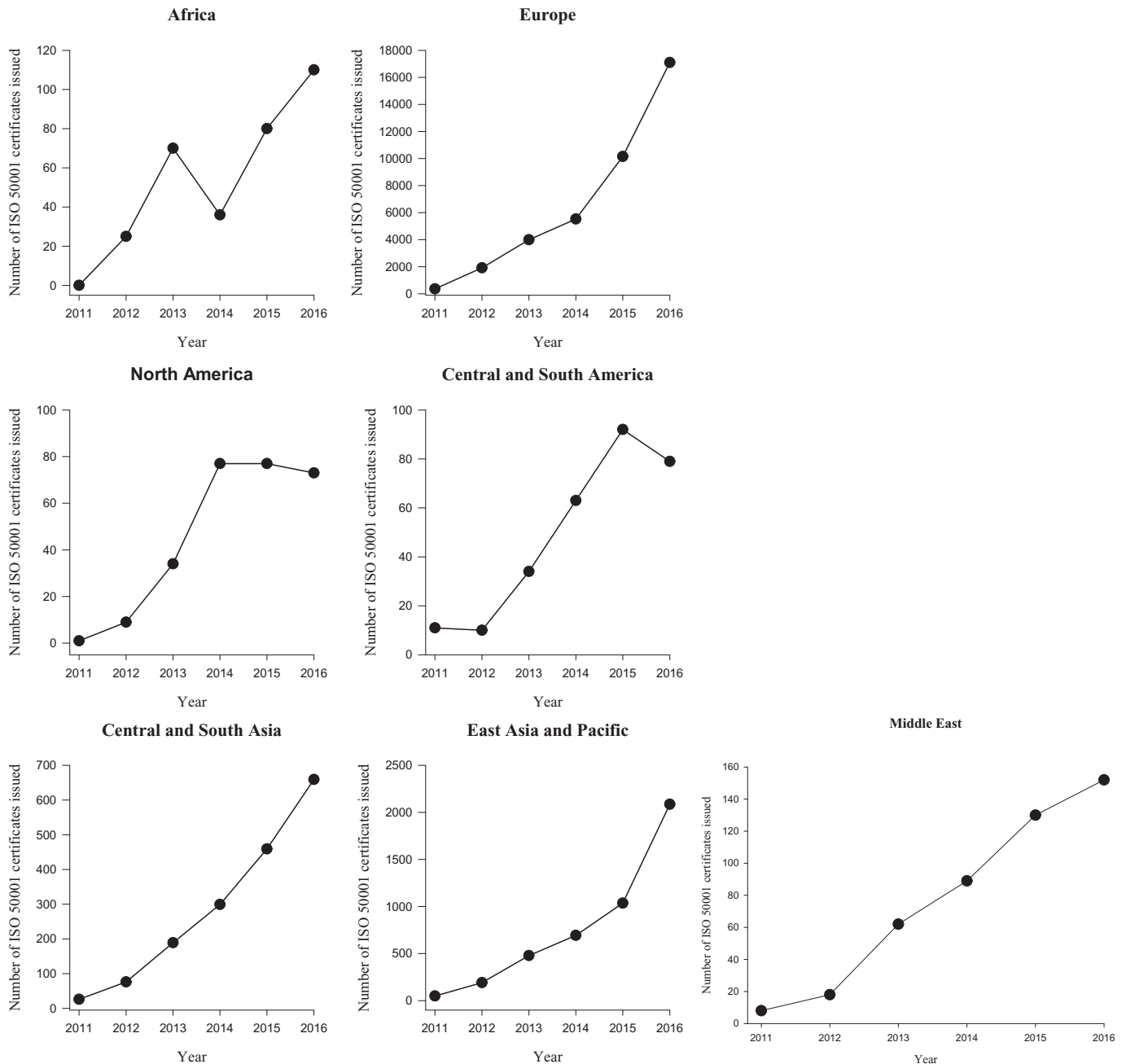


Fig. 2. Diffusion of ISO 50001 certification in the world regions from 2011 to 2016 (ISO, 2017).

negative influence on the two countries in which it was shown. In countries with more than two variables, the greatest importance of one variable was observed in relation to another. In this case, in the United Kingdom the Alternative and nuclear energy has more influence than Electricity production from renewable sources, excluding hydroelectric. This was observed in the degree of significance of the coefficients of each variable, where Alternative and nuclear energy presented p-value of 0.0215, while Electricity production from renewable sources, excluding hydroelectric presented the p-value of 0.3367.

In the Czech Republic, the variable Energy use presented greater influence in the diffusion of ISO 50001 in relation to Electricity production from renewable sources, excluding hydroelectric. However, Austria and Poland, other countries with two influence

factors, the coefficients were not significant in relation to the diffusion of ISO 50001. In this case, other variables that were not part of this study may have greater influence in the diffusion of ISO 50001. In most countries, Intercept values were negative indicating that in the absence of the influence factors ISO 50001 certification would not occur in these countries.

However, for France, Spain, Czech Republic and Russia, Intercept values were positive indicating that even in the absence of the most influential factors in each country, ISO 50001 certification would occur due to other factors. The models tested proved that these influence factors explained more than 85% of the diffusion of ISO 50001 in the respective countries (Table 4).

Among the twelve adjusted models, half of them explained more than 90% of the diffusion behaviour of ISO 50001, while the

Table 3

The parameters of the explanatory variables that influence the diffusion of ISO 50001 in different countries.

Country	Variable	β	SE β	p-value
Germany	Intercept	-10022.66	1035.42	0.0023
	E.P.R.S.E.H.	585.16	47.42	0.0011
United Kingdom	Intercept	-8185.36	1219.16	0.0215
	A.N.E.	796.42	131.44	0.0262
	E.P.R.S.E.H.	-24.72	19.72	0.3367 ^{ns}
Italy	Intercept	-472.291	169.876	0.0690
	E.P.R.S.E.H.	36.479	8.693	0.0247
France	Intercept	663.39	69.17	0.0049
	A.S.E.D.	-51509.80	6896.09	0.0049
India	Intercept	-464.2785	129.6875	0.0373
	ISO 14001 _(n-1)	0.1187	0.0231	0.0143
Spain	Intercept	678.880012	111.768341	0.0089
	ISO 9001 _(n-1)	-0.010170	0.002435	0.0250
Czech Republic	Intercept	1255.054	277.153	0.0455
	E.U.kg.of.oil.capita	-18.068	3.634	0.0382
	E.P.R.S.E.H.	-15.849	7.139	0.1566 ^{ns}
Austria	Intercept	-241.5032	315.1859	0.5240
	ISO 14001 _(n-1)	0.4355	0.2201	0.1860 ^{ns}
	A.S.E.D.	-1480.4088	933.6361	0.2540 ^{ns}
Russia	Intercept	396.462405	66.117216	0.0092
	ISO 9001 _(n-1)	-0.030235	0.005671	0.0129
Denmark	Intercept	-18.504701	16.053531	0.3326
	ISO 9001 _(n-1)	0.037852	0.008311	0.0198
Turkey	Intercept	-78.560694	14.631074	0.0126
	ISO 14001 _(n-1)	0.064164	0.007179	0.0029
Poland	Intercept	-132.29449	18.10147	0.0182
	ISO 14001 _(n-1)	0.05301	0.01518	0.0731
	E.P.R.S.E.H.	4.50812	2.27177	0.1856 ^{ns}

other half explained above 80%. In addition, all models were significant in relation to ANOVA, indicating that the variations of the ISO 50001 certifications in this period were due to the factors tested. This behaviour was represented when we compared the evolution of ISO 50001 with the factors for each country in the same period (Figs. 3–5).

In the group of countries with the highest number of ISO 50001 certifications (Fig. 3-A), the similar behaviour between ISO 50001 and Electricity production from renewable sources, excluding hydroelectric curves was observed in Germany which showed steady growth between 2011 and 2014 and a strong increase between 2014 and 2015. In the United Kingdom, where Alternative and nuclear energy and Electricity production from renewable sources, excluding hydroelectric, were the most influential factors, ISO 50001 accompanied the growth of Electricity production from renewable sources, excluding hydroelectric. However, the curve of ISO 50001 follows the behaviour of Alternative and nuclear energy, where the lowest growth occurred between 2013 and 2014 and a peak of growth between 2014 and 2015. In this last year, the three variables converge with each other. The convergence between

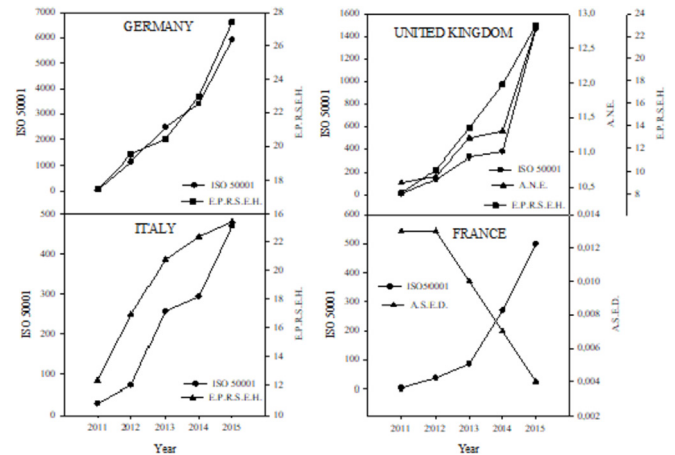


Fig. 3. Diffusion of ISO 50001 and influence factors for Germany (E.P.R.S.E.H.), the United Kingdom (A.N.E. and E.P.R.S.E.H.), Italy (E.P.R.S.E.H.) and France (A.S.E.D.) from 2011 to 2015.

variables was also observed between ISO 50001 and Electricity production from renewable sources, excluding hydroelectric in Italy, while in France the evolution of ISO 50001 differs from Adjusted savings: energy depletion with the critical point (intersection between curves) occurring between 2013 and 2014. In the second group formed by countries with intermediate certification numbers (Fig. 4), it was observed that India's ISO 50001 growth is driven by the degree of certification of ISO 14001_(n-1), however, while the latter seems to be reaching stagnation the first maintains growth. This same behaviour was observed in Spain in relation to ISO 50001 and ISO 9001_(n-1).

In the Czech Republic, the evolution of ISO 50001 is influenced by Electricity production from renewable sources, excluding hydroelectric that between 2014 and 2015 the growth of the latter boosted the former to a point of convergence. However, the reduction of Energy use, albeit to a lesser extent, had a positive influence on certifications. Also in Austria, where two factors influenced certifications, the growth of ISO 14001_(n-1) positively influenced ISO 50001, while the reduction of Adjusted savings: energy depletion influenced, to a lesser extent, the growth of ISO 50001. However, unlike India, in Austria the growth of ISO 50001 exceeded that of ISO 14001_(n-1). In the third group countries, the number of ISO 14001_(n-1) and ISO 9001_(n-1) certifications were the most influential factors (Fig. 5).

In Russia it was observed that at first the effect of ISO 9001_(n-1) is positive. However, from 2013 onwards there is a drop in ISO 9001_(n-1) certifications, but the number of ISO 50001 certifications keeps growing. The influence of ISO 9001_(n-1) is positive with both curves assuming the same behaviour, but with higher growth of ISO 50001

Table 4

Country	SW(p-value)	BP (p-value)	DW (p-value)	AIC	R ²	R ² adj	Anova (p-value)
Germany	0.100	0.530	0.468	60.38	0.98	0.97	0.001
UK	0.970	0.580	0.960	44.68	0.99	0.98	0.008
Italy	0.570	0.580	0.240	45.06	0.85	0.80	0.020
France	0.370	0.750	0.280	41.32	0.94	0.93	0.004
India	0.970	0.110	0.210	41.78	0.89	0.86	0.010
Spain	0.260	0.190	0.650	41.51	0.85	0.80	0.020
Czech	0.280	0.310	0.320	13.44	0.99	0.98	0.006
Austria	0.310	0.630	0.060	35.06	0.94	0.88	0.050
Russia	0.670	0.990	0.630	30.41	0.90	0.87	0.010
Denmark	0.140	0.220	0.100	23.15	0.87	0.83	0.010
Turkey	0.380	0.880	0.250	23.37	0.96	0.95	0.002
Poland	0.210	0.100	0.470	17.62	0.98	0.96	0.010

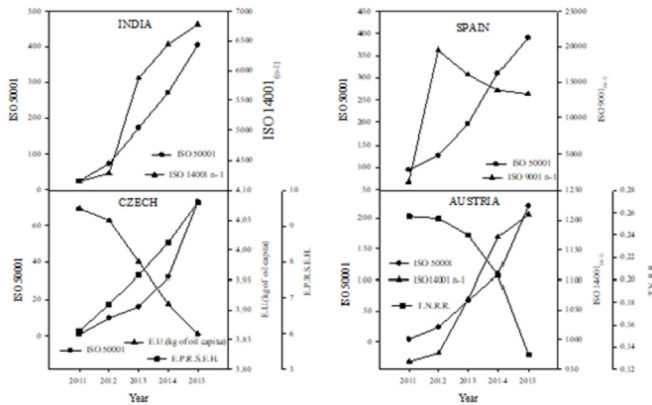


Fig. 4. Diffusion of ISO 50001 and influence factors for India (14001_{n-1}), Spain (ISO 9001_{n-1}), the Czech Republic (E.U.kg of oil per capita and E.P.R.S.E.H.) and Austria (14001_{n-1} and T.N.R.R.) from 2011 to 2015.

certifications. Turkey, like India, was a country in which the diffusion of ISO 50001 was influenced only by ISO 14001_(n-1).

The increase of the latter promoted the growth of ISO 50001 certifications. In the last observed country, Poland, the evolution of ISO 14001_(n-1) and Electricity production from renewable sources, excluding hydroelectric influenced the diffusion of ISO 50001. However, the last factor had greater influence on the behaviour of the standard. This resulted in the convergence of the two variables in 2015. The results showed that increasing the percentage of Energy use from renewable sources, excluding hydroelectric power is one of the main factors influencing ISO 50001 certifications.

This indicator is related to countries concern to reduce GHG emissions and combat the effects of global climate change (Panwar et al., 2011). Thus, countries with the largest number of companies that use or produce renewable sources of energy have high numbers of ISO 50001 certifications. Therefore, Germany that concentrates the largest number of companies that adopt EnMS also has the largest industrial park supplier and consumer of renewable energies (Bernhardt and Böttner, 2017). Since the adoption of EnMS is related to the reduction in GHG emissions, these companies seek to produce renewable energy with low environmental impact and high efficiency to try to reduce the production and consumption of energy from fossil fuels.

According to the data, companies that use or produce renewable energy seek to adopt EnMS, as observed in Italy and the United

Kingdom. However, in the latter country, the increase in the use of alternative and nuclear energy has led to the growth of ISO 50001 certifications more than renewables. In this case, unlike the increase in the use of energy from renewable sources, which is a measure that seeks to reduce the effects of climate change (Perry et al., 2008), the use of nuclear energy aims to increase the supply of energy and reduce GHG emissions (Iwata et al., 2010; Suri and Chapman, 1998; Winteringham, 1988).

Perhaps because of this, companies in this sector have sought to adopt EnMS in their operations. Thus, while companies in these countries seemed concerned about reducing the impacts of climate change, the economic factor seems to have been more important for French companies. In this country, the reduction in the economic reserves destined to attend the energy exhaustion was the main factor in the growth of ISO 50001 certifications. In this way, the companies could have adopted EnMS seeking to increase its energy efficiency by means of the reduction of costs in the production or in the energy consumption (Marimon and Casadesús, 2017).

In countries with intermediate certification numbers, the main factor influencing the growth of ISO 50001 was previous year's certifications of ISO 14001 and ISO 9001. Thus, India, Spain and Austria were countries in which the fact that the company already had these standards facilitated the adoption of EnMS. This behaviour is in line with what led ISO to integrate all these standards into a single management form (Miles and Russell, 1997).

In addition, due to initial costs and operational issues, it is easier for companies that already have some certification to adopt new management systems (Boiral et al., 2017). Unlike these countries, the growth of ISO 50001 in the Czech Republic was due to the reduction of energy use from oil. In this case, companies that have sought to reduce energy production or consumption from this source have adopted EnMS as a solution to reduce GHG emissions and combat climate change. The use of energy from oil is responsible for the emission of 78% of GHG. Thus, companies that adopt EnMS seek to substitute or improve the model of production and/or energy consumption to increase efficiency and reduce environmental impacts, especially in the emission of GHGs (energy oil equivalent per capita). In the countries of the last group, ISO 50001 certification was again influenced by ISO 14001_(n-1) and ISO 9001_(n-1). However, there are some differences when comparing Russia, Poland and Turkey with Denmark. The latter is a country with good environmental indicators in terms of public policies and legislation concerned with environmental issues (Lipp, 2007).

Other countries, apparently, seek certification as a way to adapt to demanding consumer markets. In this sense, companies that have already adopted some ISO standard have less difficulties in adopting new standards (Casadesús et al., 2008). With this, certified companies can expand their products or services by improving their image in the market through green marketing, where the idea of sustainability and efficiency becomes the main benefits of certification (Fonseca et al., 2017).

Climate change, and consequently the increase in energy use from renewable sources, was the main factor in the diffusion of ISO 50001 certifications. Because fossil fuels are the main source of GHG emissions and the energy sector uses large quantities of these fuels (Weisser, 2007), the search for renewable energies as well as the adoption of EnMS are aimed at reducing the emission of GHG by companies in the energy sector (Fiedler and Mircea, 2012; Viebahn et al., 2007). However, this behaviour seems to be related to countries with the highest number of certifications. In these countries, legislation and public policies to encourage sustainable development can act as a catalyst for the growth of renewable energy use, hence ISO 50001 (Duffield, 2009).

On the other hand, the socio-cultural factor also presented great

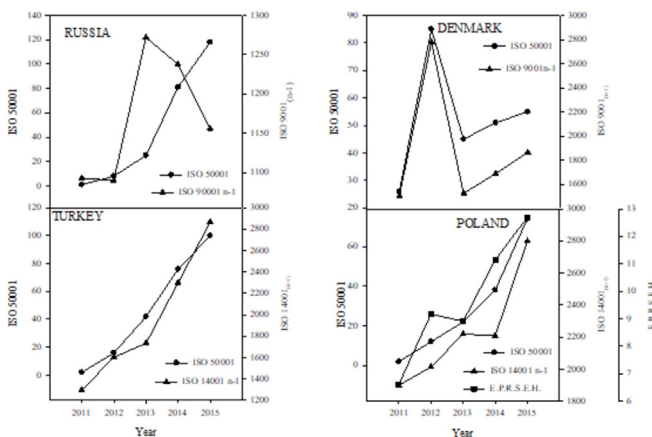


Fig. 5. Diffusion of ISO 50001 and influence factors for Russia (9001_{n-1}), Denmark (ISO 9001_{n-1}), Turkey (14001_{n-1}) and Poland (14001_{n-1} and E.P.R.S.E.H.) from 2011 to 2015.

importance in the diffusion of ISO 50001. Based on the number of ISO 14001 and ISO 9001 certifications of the previous year, companies that adopted EnMS possibly already had one of these two standards. The fact that the company already has a management system facilitates the adoption of new standards (Neves et al., 2017).

In some cases, the growth of older standards (ISO 14001 and 9001) drove the diffusion of ISO 50001, but in other situations, the countries were in mature and/or retrogressive states in relation to older standards and even growth of ISO 50001. This is due to the interval between releases of the standards. Thus, the previously released standards reach very high numbers and enter the dynamic equilibrium (where certification and decertification are equivalent) (Lira et al., 2018). On the other hand, the latest standards are adopted by those companies that already have the older standards, besides the companies that appear in that period (Marimon et al., 2010, 2006; Morrow and Rondinelli, 2002; Perkins and Neumayer, 2010; Wisdom et al., 2014).

This caused some countries to exhibit the exponential growth of ISO 50001, even when the patterns of influence were in dynamic or retrogressive equilibrium. However, the socio-cultural factor for some countries can also be treated as an economic factor. Since, the cost of implementing a management system in a company that already has some type of this system is cheaper compared to the companies that implement it for the first time (quote). Moreover, increasingly demanding emerging markets with large energy sources need certifications to trade their products and services in some of the most important consumer markets (Marimon and Casadesús, 2017). In this way, the diffusion of ISO 50001 accompanies different environmental, socio-cultural and economic movements (Duffield, 2009).

5. Conclusion

According to this work, the diffusion of ISO 50001 among countries with the highest number of certifications is influenced by the fight against climate change, increasing the use of renewable energy sources, and by prior adoption of ISO 9001 and ISO 14001. These two factors are responsible for the dissemination of ISO 50001 in eight of the twelve countries analysed. The predominance of these two factors shows that the reduction of GHG emissions, reduction of costs of implementation of management systems and search for greater acceptance in the consumer markets were the topics that designed the diffusion curves of ISO 50001 in the countries that had the highest number of certifications. These factors may act together, but as a matter of priority, a factor becomes dominant in the diffusion behaviour. However, the low number of observations due to the short launch period of the standard and the lack of data for some countries made it difficult to analyse more accurately. Nevertheless, these data have made it possible to draw a profile of countries on the adoption of EnMS, which has emerged as an essential energy management system to ensure energy supply and mitigate the environmental impacts of the sector. In this way, countries with the highest degree of investment in renewable energy will remain with the highest growth in ISO 50001 certifications. Countries that follow previous standards may begin to reduce growth as the number of companies adopting EnMS approaches the number of companies that already have ISO 14001 and/or ISO 9001. In this respect, the trend in countries with low ISO 50001 certifications is that the growth of this standard is driven by the adoption of older standards. Although, as observed in this work, this effect has a temporal leg, which for the countries with the highest number of certifications was one year, but in these other countries the leg may be larger. Finally, future work needs to include countries with fewer certifications, increase the number of factors, and

extend the observation period. In addition, this work opens a door for detailed investigation in each country of the factors that lead to this diffusive behaviour, following the methodology and inferences of the present article. Yet, the latter has the natural limitation of time. The results and analyses that have been raised in this article can be used by decision-makers as how to invest to increase the diffusion of ISO 50001, as this standard is becoming increasingly important and seems to be essential to guarantee energy supply and combat climate change.

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